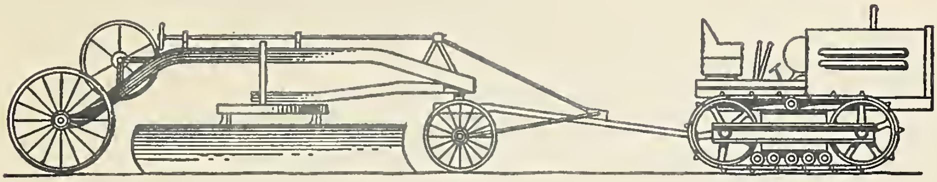
CONSTRUCTION



HINTS

UNITED STATES DEPARTMENT OF AGRICULTURE, FOREST SERVICE
WASHINGTON, D.C.

Volume 6 | October 1940 | Number 10

The August issue of Construction Hints carried an erratum for Engineering Field Tables. Another error has recently been called to the attention of this office. In Table XIV, Natural Sines and Cosines, page 48, the sine of 39°-19' should be 0.63361. Anyone using these tables should make this correction therein.

This entire issue has been devoted to an article, "Durable Concrete", by C. A. Betts of the Washington office. Mr. Betts has included much information valuable to the construction crew in the selection of materials, designing of mixes, mixing and placing, curing, waterproofing, and testing to permit the making of durable concrete. Such a concrete is needed in National Forest work.

E. S. MASSIE, Jr.,
Editor.

DURABLE CONCRETE

C. A. Betts

Durable concrete is strong; strong concrete may not be durable. A rich mix that is honeycombed may have high compressive strength yet permit water to enter and deteriorate the concrete through leaching and frost action. There may even be contiguous voids that make the concrete porous. Inasmuch as it is true that the same factors that make concrete dense and durable also provide greater compressive strength, it is better to aim at a dense, impervious concrete than to merely seek strength. A dense, durable, impervious concrete is needed in the National Forests where most of the concrete is exposed to moisture and where permanence is vital. The improvement program must not be handicapped by replacements of supposedly sound concrete.

How to make durable concrete is the problem of every concrete construction crew. The following Construction Hints on

Selection of materials,
Designing mixes,
Mixing and placing,
Curing,
Waterproofing,
Testing,

are intended to give helpful information. Reference should also be made to the Forest Service Concrete Specifications published in Chapter IX of the Truck Trail Handbook and in Appendix C of the Water Developments and Sanitation Handbook.

SELECTION OF MATERIALS

All Sources to be Investigated

It pays to "shop around" for the best source of sand and coarse aggregate. This not only saves money and cement, it produces better concrete.

Pitfalls to Avoid in Selecting Sand and Gravel Pits

Of two gravel pits, for instance, one may yield such an excess of fines that the cost of screening plus the wastage will be very high while the other pit may contain an ideal gradation all the way from the maximum size needed down to fine sand. Natural deposits are frequently too fine to be economical. A pit having

too much material of one size will have to be worked over with crusher or screens or both if harsh concrete with too many voids is to be avoided. Pit-run mixtures of fine and coarse aggregates practically always need to be screened and recombined in the proper proportions for best results.

Ways of Recognizing Suitable Materials

How to know the best material is the question. By the use of the simple tests for organic impurities, for clay (or silt), and for gradation, which are given under Tests Nos. 1, 2, and 3, on pages 15 and 16 of Appendix C of the Water Developments and Sanitation Handbook, it is possible to determine which aggregates are most suitable.

Mechanical Analyses

A set of standard Tyler sieves and scales should be available for every concrete job and the gradation of practically all aggregates that are proposed for use should be tested. These sieves will also come in handy in designing stabilized roads. Even on a small job it will pay to run a quick test, using short cuts such as eliminating some of the screens. Seldom is it that a pit-run has the right proportions without at least one screening and still more seldom can the quality of the pit be accurately sized up by observation alone. As a result much good cement and time have been wasted for lack of a few hours of preliminary investigation.

Fineness Modulus

Fineness modulus is a big name for a simple, convenient way of designating size range. There is nothing complicated about it. Just add together the proportions retained on sieves #100, #50, #30, #16, #8, #4, 3/8", 3/4", 1", 1-1/2", and divide by 100. If there is only sand the percentages retained on screens larger than #4 will be zero. If the fineness modulus is very high the aggregate is harsh and unworkable; if very low there are too many fines for economy.

The usual f. m. limits are 2.50 to 3.50 for sand, 7.5 to 8.5 for coarse aggregate and 4.5 to 6.5 for mixed aggregates.

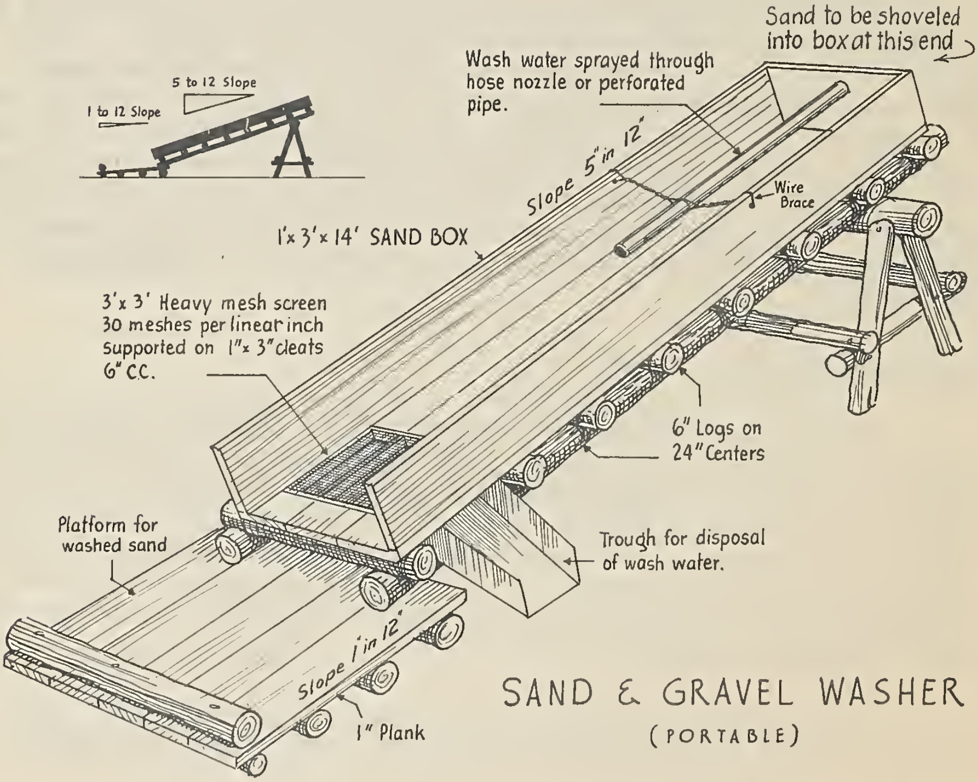
Dirty Sand

Dirt has been a common source of defective concrete in the past. It is important to differentiate between the dirty, bond-weakening coatings that prevent the hardening of cement and the

very fine rock powder which may prove an asset in filling the finer voids. Sometimes washing is allowed to remove too much of the fine material along with the dirt. Above mentioned tests #1, #2, and #3 will tell the story. If the sand requires washing a home made rig like that shown in Figure 1 may serve the purpose.

The washer should be adjusted and operated in such a manner, that the dirt rather than the fine sand, is removed. Results of washing can be checked by the above mentioned tests.

FIG. 1.



SAND & GRAVEL WASHER
(PORTABLE)

Aggregate Sizes

Too many fines requires extra water and cement and lead to an uneconomical mix not to mention the tendency for the resulting concrete to become porous when the excess water dries out. Too much coarse material tends to produce harsh, honeycombed mixtures.

Maximum Coarse Aggregate Size

There is much economy to be gained by using as large coarse aggregate as circumstances permit, but the largest stone should not exceed one-fifth the thickness of the concrete section or three-fourths of the minimum opening between reinforcing bars. Generally the maximum size is 2-1/2", 2", or 1-1/2" although as low as 3/4" is sometimes necessary.

Plums

"Plums," or large stones, can be washed and thrown into the concrete to save cement or coarse aggregate. While plums are permitted in mass concrete provided they do not constitute more than twenty percent of the total volume of concrete and are kept 12" apart, it has been found that there is generally no saving in handling them as compared to mixer run.

Physical Properties of Aggregates

It is not always easy to recognize weak rock, yet shales, laminated structures, and soluble varieties of stone are easily identified. Furthermore, strength tests of the concrete will determine if the weakness lies in the coarse aggregate or in the bond between it and the mortar.

Comparative Estimates of Cost of Aggregates

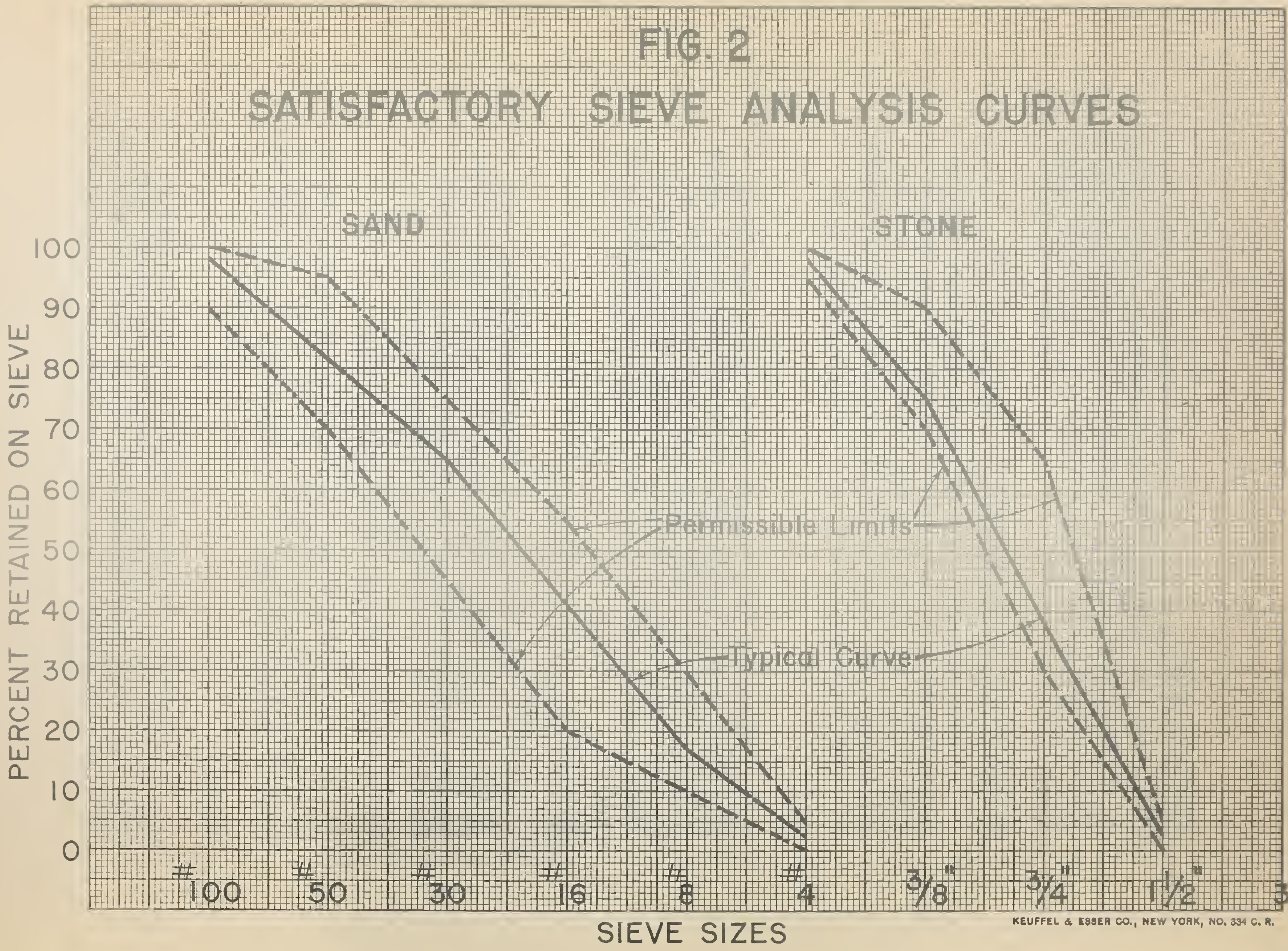
An hour spent by the engineer figuring the cost of removing overburden, screening, and hauling against the cost of shipping-in proven aggregates has been known to save many man-hours or dollars on a job.

Tolerance

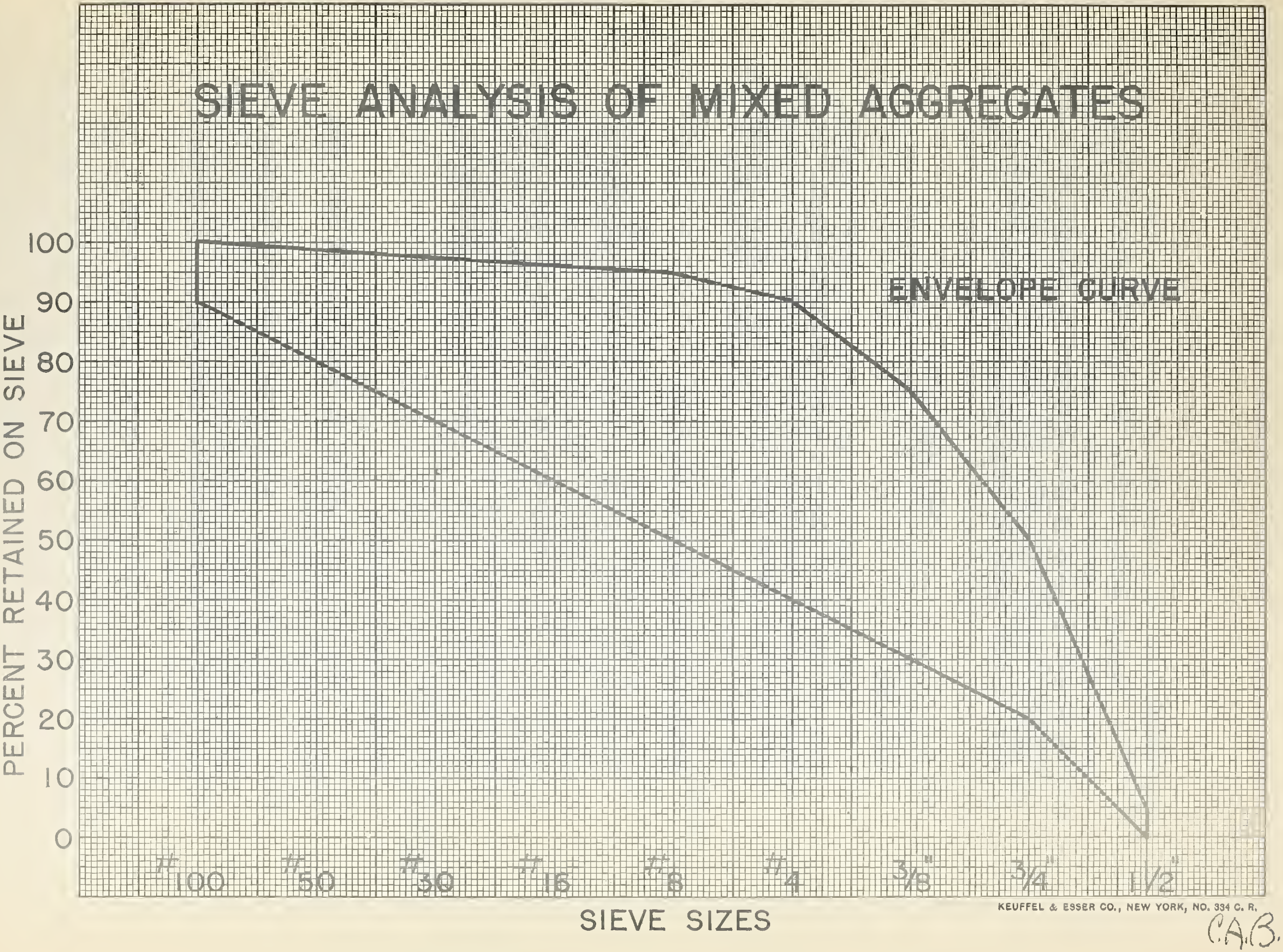
Permissible variation in sizes (see Fig. 2) permits wide latitude in the selection of suitable aggregates, but there is a limit beyond which it is impossible to go and still obtain good concrete.

FIG. 2

SATISFACTORY SIEVE ANALYSIS CURVES



C.A.B.


SIEVE ANALYSIS OF MIXED AGGREGATES
ENVELOPE CURVE
PERCENT RETAINED ON SIEVE
100
90
80
70
60
50
40
30
20
10
0
#100
#50
#30
#16
#8
#4
3/8"
3/4"
1 1/2"
SIEVE SIZES
KEUFFEL & ESSER CO., NEW YORK, NO. 334 C. R.
C.A.B.

Cement

Federal Specifications SS-C-191A and SS-C-201 cover normal and high-early-strength cements. In July 1940 American Society for Testing Materials adopted standard specifications for "Moderate heat, low heat, sulphate resisting" cements. Cement content of concrete usually ranges from four to eight sacks per cubic yard of concrete.

DESIGNING MIXES

1:2:4 Mix

The proverbial 1:2:4 mix has been greatly overworked. Like the saying, "A pint's a pound, the world around," it is being superseded with more scientific procedure. Designed mixes based on characteristics of materials and requirements are giving better concrete at lower cost. The larger the job, the more scientific the design, the greater the saving.

Methods of Proportioning Materials

To be sure the ratio of sand to cement usually ranges between 1 and 3 and the total weight of fine aggregate is usually between 1/3 and 2/3 of the total weight of fine and coarse aggregate combined. Nevertheless it is obvious that, in order to have a dense mix there must be different proportions of mortar to fill the voids of the various combinations of aggregates, no two of which are alike. Among the methods used for designing mixes are "Maximum Density Grading," "Aggregate Void," "Water-cement," "Trial batch," and "Spit and Guess."

Maximum Density Grading

Good gradation reduces the percentage of voids thus producing greater density.

The use of sieve analysis as a basis for the proportioning of various sizes of aggregates so as to obtain the greatest density in the finished concrete is described in "Design and Control of Concrete Mixes," published in 1927 by the Portland Cement Association.

Basic data required in addition to mechanical analysis, is weight per cubic foot and specific gravity of the sand and stone.

A quick way to size up results of a mechanical analysis is to plot them for comparison with a satisfactorily graded aggregate, such as is shown on Fig. 2 or on Fig. 3. Many engineers keep such standard "envelope curves" for reference to show up deficiencies in samples being tested.

The combination of this latter grading method with the water-cement control described below gives good results.

Aggregate Void

The design of mixes by the use of triaxial graph on which percent of voids in sand and gravel are plotted is described on Page 9 of Stabilized Soil Roads. This method requires considerable time.

Water-Cement and Trial Batch (Most appropriate for U.S.F.S.Work)

Concrete mixes based on water-cement ratio with aggregate proportions determined by trial batches can be designed as described in "Design and Control of Concrete Mixtures" published by the Portlant Cement Corporation.

This simple method is predicated on the fact that, for given conditions of mixing, placing, and curing, the strength of a mix depends on the proportion of mixing water to cement providing the mix is workable.

$$\text{Water-Cement Ratio} = \frac{\text{Volume of water in cu.ft.}}{\text{Volume of cement in cu.ft.}}\left(7.5\right) = \frac{\text{gals.of water}}{\text{sacks of cement}}$$

Fig. 4, recently published by the American Society of Civil Engineers, contains a number of typical mixtures for a number of water-cement ratios ranging from 1 to .7 with their corresponding strengths from 2250 to 4259. It will serve as a guide for cement content between the limits of 4 to 8 sacks per cubic yard. In cases where the job is so small that elaborate preliminary tests and computations for the design of the mix seem impractical, this Figure 4 will be found very valuable.

The best way to use the table, (Fig. 4), is to select the mix that appears to meet the requirements and mix several trial batches, using the maximum percentage of coarse aggregate

FIG. 4

APPROXIMATE QUANTITIES OF MATERIALS FOR CONCRETE
For Use as a Guide or Where it is Impractical
to Make Tests.*

Max. Size Coarse Agg. (Ins.)	Estimated 28-Day Comp. Strength (Lbs. per Sq. In.)	Sacks Cement per cu.yd. Concrete	Max. Water per Sack Cement (Gal.)	Fine Agg. % Total Agg. Approx.	Approx.Wts.Surface-Dry Agg.per Sack of Cement (Lbs.)			Mix By Wt.
					Total	Fine Agg.	Coarse Agg.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	2,250	4.9	8	40-46	660	280	380	1:3 :4
2	2,250	4.5	8	37-43	740	300	440	1:3.2:4.7
3	2,250	4.1	8	34-40	840	310	530	1:3.3:5.6
1	2,750	5.6	7	39-45	570	240	330	1:2.5:3.1
2	2,750	5.1	7	36-42	640	250	390	1:2.7:4.15
3	2,750	4.7	7	33-39	720	260	460	1:2.8:4.9
1	3,000	6.0	6½	38-44	520	210	310	1:2.2:3.3
2	3,000	5.5	6½	36-42	590	230	360	1:2.5:3.8
3	3,000	5.1	6½	34-40	660	240	420	1:2.5:4.5
1	3,300	6.5	6	37-43	470	190	280	1:2 :3
2	3,300	6.0	6	35-41	530	200	330	1:2.1:3.5
3	3,300	5.5	6	33-39	600	220	380	1:2.4:4
1	3,700	7.2	5½	36-42	420	160	260	1:1.7:2.8
2	3,700	6.7	5½	34-40	470	170	300	1:1.8:3.2
3	3,700	6.2	5½	32-38	530	180	350	1:1.9:3.7
1	4,250	8.0	5	35-41	370	140	230	1:1.5:2.5
2	4,250	7.4	5	33-39	420	150	270	1:1.6:2.9
3	4,250	6.8	5	31-37	470	160	310	1:1.7:3.3

* Above values based on use of normal cement, aggregates having a specific gravity of 2.65 and concrete having a slump of about four inches. To reduce slump 1" reduce cement content 1/8 sack per cu. yd. To increase slump 1" increase cement content 1/8 sack per cu. yd. For different specific gravity multiply Col. 7 or 8 values by ratio of actual specific gravity to 2.65.

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that will make a workable mix. Increasing the quantity of coarse aggregate tends towards a larger yield and greater economy, providing it does not produce harshness and thereby increase the cost of placing. Increasing the fine aggregate tends to require more water, therefore an increased amount of cement, if a prescribed strength is to be maintained. On the other hand, where improved quality is sought a reduction in the water-cement ratio, with or without increase in cement content, may be necessary.

In proportioning by this method it will be found very helpful to use well graded aggregate; in other words, it will pay to make a sieve analysis, determine the fineness modulus of the material and, if necessary, adjust the percentage of certain sizes of aggregate by screening and recombining.

It will also be very helpful if comparative strength tests of trial batches can be made to accurately determine what is to be expected of the local material. If this be done and the records are well kept, the different localities will know the value and characteristics of various sources of sand and gravel supply from which to select the most suitable. Where an impervious, durable mix is required, the mix should be designed to have a compressive strength at twenty-eight days of at least 2500 pounds per square inch.

Moisture in Aggregates

In all cases involving water-cement ratios allowance must be made for the free water already in the aggregates. To determine the moisture content it is a simple matter to weigh out a sample, drive off the free moisture by heating and then re-weigh after the material has cooled. A convenient way of drying where there is no stove is to spread sand out thinly over the bottom of a pan, pour about one-third cup of alcohol per pound of sand over the damp material and set fire to the alcohol, stirring the sand as it is being dried. The loss of weight divided by the dry weight and multiplied by 100 gives the percent of moisture. As a rough rule 2% equals 1/4 gallon water per cubic foot, 4% equals 1/2 gallon, 6% equals 3/4 gallon, 8% equals 1 gallon and 10% equals 1-1/4 gallon of water per cubic foot of material.

Another method is to add these amounts of water to a cubic foot of sand a quart at a time and become familiar with the appearance of the sand under these conditions.

Trial Batches

Regardless of how the tentative mix is designed, trial batches should be made up in order to check the workability and consistency and to determine the final instructions to the concrete crew. The better the mixer man is, the more he will favor trial batches and the more he will profit thereby.

The principle to remember is to add or deduct coarse aggregate as the first step instead of varying the water, once the water ratio has been selected. As a second step the fine aggregate can be varied and as a third step the cement; but <u>only as a last recourse should the water content of the batch be increased.</u>

Slump

Until a better criterion is devised the standard slump test, (Appendix C, Page 17, Water Developments and Sanitation Handbook) remains the accepted means of measuring the consistency or the wetness of the concrete and its suitability for the work contemplated. A slump cone can be made by any metal worker. Every job using concrete in quantity should have one and use it as insurance against sloppy concrete.

Desirable Slumps:

Mass concrete (dams, bridge abutments, pavements)	1" - 4"
Heavy walls, slabs, beams, columns, posts	3" - 6"
Thin or reinforced sections	4" - 8"

Vibrated concrete may be placed with the minimum slump.

Proportioning by Volume

A measuring box for volumetric proportioning can be readily made out of one inch boards and provided with 2" x 4"s nailed along the sides for handles. Inside measurements for 2 cubic foot capacity box can be 18" x 18" x 10-5/8". If wheelbarrows or buggies are used, cubic foot lines can be be painted on the inside, so that loading will be fairly accurate. A bottomless box can be used to calibrate wheelbarrows.

Proportioning by Weight

Weighing of the concrete materials is the simplest way to avoid errors due to bulking of sand from moisture content which may increase the volume of the sand as much as 30% in

some instances. Weighing also facilitates making allowance for moisture in the aggregates, as sand with water content can be weighed out and added to the mix until the total weight is equivalent to the required dry weight of sand plus its moisture content.

<u>The Handy "40" Rule</u>

Forty percent of the total weight of sand and gravel equals the weight of sand.

Forty degrees equal minimum permissible placing temperature.

Forty seconds equal minimum mixing time permissible.

Forty minutes equal maximum initial setting time.

Forty days equal desirable curing period.

Forty years expected life of concrete without maintenance.

<u>MIXING AND PLACING</u>

<u>Machine Mixing</u>

Concrete mixed by machine is so much more likely to be uniform and superior that hand mixing should be used only when absolutely necessary and then carefully done in a water tight box. Mixing should be continued until a homogenous mixture of the required consistency is assured.

<u>Mixing Period</u>

Many tests of the effect of length of mixing time on the quality of concrete have led to the conclusion that <u>1-1/2 minutes</u> is best. Shorter periods may give incomplete mixing; longer periods do not improve the quality enough to pay for the extra time and effort.

<u>Ready-Mixed Concrete</u>

As a general rule concrete from a truck-mounted mixer should be delivered within <u>1-1/2 hours</u> after mixing is begun,

preferably much sooner.

Loading of Mixer

When information as to the mixer loading recommended by the manufacturer is not available, a general rule of 50% of total holding capacity is sometimes observed.

Vibration of Concrete

Placing and compacting concrete by vibration permits the use of much less water and more coarse aggregate- result, a stronger, more dense, more economical product. If economy is the objective, the sand-gravel ratio can be reduced. If, in the latter case, there is bleeding of grout, more fine sand will have to be added.

Over-vibration can be recognized by the formation of grout pools or a line of cement paste at the forms. The point where the decrease in volume ceases and the mix arrives at a uniform plastic consistency is easily recognized by an experienced operator.

Vibrators should not be used to spread concrete so far that it segregates. It is better to use internal vibrators in the restricted areas in the forms which must be strong enough to withstand the extra pressure caused by the vibration.

Placing

No matter how well a mix is designed the density of the finished concrete depends to a considerable extent on the placing and curing.

Concrete should be deposited where it is to go with a minimum of disturbance or segregation. For this reason the use of long chutes or long drops without elephant trunks, or the depositing of concrete under-water without tremies impairs its quality. Wheel barrows or buggies do best on smooth runways. Dump buckets give good results.

It is generally agreed that concrete should never be placed after it has begun to set, which is normally about 30 minutes after leaving the mixer.

Placing Concrete Under Water

The placing of concrete in still water can be successfully accomplished by the following methods:

1. Tremie. By keeping the watertight pipe full of concrete and having the outlet end at the point of deposit a steady, undisturbed flow can be discharged and spread by slowly moving the tremie. Slump shall be 5 to 7 inches.

2. Bottom dump bucket. A full bucket with open top and drop bottom is lowered slowly until it stands where the concrete is to go. Then the bottom gate is opened and the bucket slowly raised, allowing the concrete to subside into position.

3. Bags of concrete. By filling burlap bags 2/3 full and tying them securely they can be laid in position like masonry, care being taken to obtain an interlocking bond by alternating bundles.

Construction Joints

It is not always practical to deposit concrete continuously until a structure is finished, but it is possible to prevent the joints, where fresh pours are made, from becoming planes of weakness in the mass.

One of the secrets of accomplishing this is to remove all laitance and roughen the surface of the concrete before a new pour is made.

Another method is to place the joints where they will receive the least displacement pressure after the work is completed.

Still another way is to coat the old surfaces with 3/4 inches of neat cement grout immediately before pouring the new concrete.

Reinforcement continues through construction joints, but not through contraction joints. Where there is no reinforcement, concrete keys or dowels to prevent sliding at the joint may be required.

Contraction Joints

The function of contraction joints being to control cracks due to expansion or contraction, it is desirable that they be located sufficiently close together to prevent intermediate cracking. In retaining walls this means about every 30 feet in plain concrete, 100 feet in reinforced walls; in dams, about every 30 feet, in pavements about every 20 feet, and in buildings about every 200 feet as well as at L, T and U breaks.

Reinforcement can take the place of joints in short structures. Although reinforcing steel does not extend through a contraction joint, there will be cases where extra reinforcement bars will be needed in the concrete on each side of the joint. Joints having interlocking keys can function without lateral displacement. They should be continuous. In a building, for example, there should be an unbroken joint or plane of separation from top of footings to roof.

Joint fillers may consist of premoulded asphalt, asphalt, bentonite, cork, or other compressible material that will keep water from the joint without inhibiting its movement. Joints exposed to water pressure can be made water tight by using a continuous waterstop of 23 gauge copper embedded in the concrete on each side of the joint and folded at the joint to take care of expansion and contraction.

Joints should be located by the designer so as to take into consideration not only the stresses that will develop in the structure, but also its appearance and serviceability.

Steel Reinforcement

In placing reinforcement bars it is important not only that concrete fill all the space around the steel but that at least two inches of concrete serve as a protection from outside moisture or fire. Where there is direct water contact with the surface 3" is preferable to 2".

CURING CONCRETE

Moisture Control

Paradoxically, concrete should not have excess water content, yet it must be kept wet during the first week or two. The reasons are simple. Extra water that cannot go into chemi-

cal action in the setting process will evaporate, leaving voids or minute honeycomb which can subsequently absorb free moisture that may freeze or crack concrete or that may leach out chemical constituents. On the other hand, by keeping the concrete damp so that there is no loss of water from the surface during the period of setting there is sure to be adequate moisture to cause full rather than partial chemical combination.

Forms

Absorbent form lining fulfills these requirements by removing the excess moisture, yet preventing too rapid evapor ation or drying out. (Nuwood, Celotex, Firtex, and a number of other makes of absorbent form are being put on the market. See "Aesthetic Treatment of Exposed Surfaces," by Ellis Groben for discussion of forms, colors of concrete and other surface considerations.

Removal of forms tends to more rapid drying unless moisture is applied. On the other hand early removal may be desirable to permit work on the fresh surface or in order to reuse forms. Where no load is carried forms may be taken off in twelve hours in warm weather, but where loaded both forms and falsework should remain in place from one to three weeks.

Preventing Premature Drying of Concrete

Prevention of evaporation loss may be accomplished by
(1) Leaving forms on the concrete,
(2) Covering the concrete with 1" wet sand or other material such as wet burlap, cotton mats, heavy paper, 6" hay, straw, sawdust,
(3) Continuous sprinkling,
(4) Ponding (for horizontal surfaces),
(5) Membrane Coating.

Anti-Freeze

In cold weather it is necessary to protect concrete from freezing for at least 72 hours after placing or until most of the water has gone into chemical combination. The temperature of the concrete should not fall below 40^{o} for at least two weeks after placing and preferably should be kept above 50^{o}. In massive sections, such as dams and bridge abutments, the chemical heat generated by setting would be as much as 60 degrees, but in thin sections, such

as are usually encountered, this heat rapidly dissipates by radiation and it is necessary to apply heat to the concrete materials and to the concrete so that at all times temperature will remain above 50 degrees. For pre-heating of aggregates an 18 inch corrugated metal culvert pipe placed on an incline, so that a fire built at one end will draw, makes a good heater around which to store sand or gravel prior to mixing. For keeping concrete warm, salamanders made of old oil drums by removing the top and adding legs and draft holes give good service.

If manure is used as a protection from freezing it should not be in contact with the concrete. Admixtures such as salt are not recommended.

Curing Time

Curing should continue for from 7 to 14 days at least and preferably for 40 days as concrete needs moisture for weeks to complete chemical setting. Premature drying out will rob the concrete of over half of its ultimate strength possibilities. Curing at 70 degrees gives about double the strength obtained by curing at 30 degrees. In fact, curing has a greater effect on the ultimate quality of concrete than is usually realized. It is poor economy to add a sack of cement per cubic yard to compensate for faulty curing.

WATERPROOFING CONCRETE

The first step in preventing the passage of water into or through concrete is to make impervious concrete. Properly cured, rich mixes with low water-cement ratio give this. Class A concrete complying with Forest Service specifications will be dense and will withstand high water pressures. If cracks or honeycomb occur, however, leakage may develop.

In this case some external protective treatment may be needed. Naturally it is better to apply this protection on the side where the water is. Where this is impossible, however, and the other side can be protected from freezing that would spall off concrete beneath the coating, it is possible to treat the side away from the water source.

Portland Cement Mortar

A 1:2 mortar, consisting of 1 part cement to 2 parts sand, carefully plastered on the water side to a thickness of

$3/4"$ (in two coats) will be effective (until disturbed) if applied to a clean roughened surface where cracks have been chipped out and blocked with mortar. In fact no surface coatings should be placed over open cracks.

Bituminous Membrane Coats

Widespread application is made of bitumen-saturated felt or fabric in several layers, held together and to the concrete by asphalt or tar coatings. This waterproofing must be protected from punctures.

Bituminous coatings, whether applied hot or cold, are used on the outside of foundation walls and elsewhere to impede moisture and to protect concrete from chemicals in groundwater. They are not as heavy as membrane coats nor as expensive but fulfill many requirements.

Damp-Proofing

Some methods rely on waterproof paints, resinous varnishes, linseed oil, cement paint, or powdered iron paint applied to the surface or water repellent materials incorporated in the mix.

Admixtures

The value of the admixtures for damp proofing being largely in making a mix more workable, it is usually equally effective to add more cement instead of the admixture and thereby gain both plasticity and strength with a known ingredient.

Drainage

Draining water away from a structure may obviate the necessity for expensive waterproofing.

TESTING CONCRETE

Testing Facilities

Field tests of concrete offer a good means for controlling the quality and, at the same time, a good record of what sort of concrete went into the structure. If this were not so, it would not be such universal practice throughout

the country. Without tests a crew can go on indefinitely making mistakes without knowing it.

On sizeable structures advantage should be taken of National Forests' equipment and facilities, but where there are no testing facilities near by, it may be necessary to arrange with the Highway Department, university, or other laboratory to handle control specimens. Some of the Regions find a portable beam-breaking apparatus satisfactory for strength tests.

Number of Specimens

As a rule three cylinders or beams are made for each day's run unless more are required to give adequate control.

Curing and Storing Test Specimens

If cylinders, cubes, or beams that are to be tested are stored in the field under conditions identical with those prevailing at the job, the strength tests made more nearly reveal the strength of the concrete in the structure. However, cylinders cured in a water tank or by storage in damp sand offer more reliable comparative data and are to be preferred because of the difficulty of properly handling specimens that are cured in the field and then rushed to the laboratory for breaking. Cylinders should be capped to present uniform bearing area and tests should be standardized as much as possible so that results will be comparable. (See Appendix C, page 18, Water Developments and Sanitation Handbook).

Seven Day Tests

Since it is impracticable to wait twenty-eight days for field control tests, seven day strength tests can be made and the results converted to twenty-eight day strength by the following formula:

Twenty-eight day strength equals 1.51 times the seven day strength plus 49.

$$S28 = 1.51\ S7 \text{ plus } 49 \text{ or}$$
$$S28 = S7 \text{ plus } 30\sqrt{S7}.$$

Where high-early strength cement is used, the three and seven day tests give results comparable to seven and twenty-eight tests respectively for normal cement.